supplemented by reference to measured values of radiation.

The paper then presents in tabular form [11] the values of radiation, in gram-calories per minute per square centimeter, with clear sky and with mean cloudiness received at Potsdam at each hour of the day at the middle of each month of the year on ten differently exposed surfaces as follows: Plane normal to the direction of the rays (total intensity), horizontal plane, walls facing north, east, south, and west, and slopes of 30° facing the above directions.

From values for clear sky there has been constructed for presentation here Table 1 showing values of radiation at 11 a. m., when the intensity of full radiation is only slightly below the maximum.

The maximum values of solar radiation with clear sky under different exposures are given in Table 2. It is to be noted that these values like those preceding relate to the middle of the month.

Table 3 (part of Table 5 in the original paper) gives solar radiation with average cloudiness, the actual radiation received, at Potsdam during one day at the middle of each month of the year.

Assuming that the mid-month values are average values for the month, Schubert presents a table of mean daily amounts of solar radiation received with clear sky and also with average cloudiness (at Potsdam) during the period from April to August, inclusive, which he calls the main growing season (*Hauptvegetationzeit*). These values which are of special interest to the agriculturist, are given in Table 4.

—Selected text translated by W. W. R.

TABLE 1.—*Solar radiation (gram-calories per minute per square centimeter) with clear sky at 11 a. m. at the middle of the month. Potsdam*

Exposure	January	February	March	April	May	June	July	August	September	October	November	December
Under normal incidence (total intensity)	0. 98	1. 11	1. 11	1. 26	1. 28	1. 27	1. 19	1. 15	1. 21	1. 16	0. 97	0. 93
On horizontal plane	. 26	. 45	. 62	. 90	1. 04	1. 08	1. 00	. 88	. 77	. 54	. 30	. 21
On east wall [1]	. 24	. 28	. 29	. 32	. 31	. 32	. 29	. 29	. 31	. 30	. 24	. 22
On south wall	. 91	. 98	. 87	. 82	. 67	. 58	. 58	. 68	. 89	. 98	. 89	. 88
On north slope of 30°	. 00	. 00	. 10	. 37	. 56	. 65	. 58	. 42	. 22	. 00	. 00	. 00
On east slope of 30° [2]	. 34	. 53	. 68	. 94	1. 06	1. 09	1. 00	. 91	. 82	. 62	. 38	. 29
On south slope of 30°	. 68	. 88	. 97	1. 19	1. 24	1. 23	1. 15	1. 11	1. 11	. 96	. 71	. 62
On west slope of 30° [3]	. 10	. 25	. 39	. 62	. 74	. 79	. 72	. 62	. 51	. 32	. 14	. 07

[1] On west wall at 1 p. m. [2] On west slope of 30° at 1 p. m. [3] On east slope of 30° at 1 p. m.

[11] Also in isopleths for radiation with clear sky.

TABLE 2.—*Maximum values of solar radiation with clear sky for different exposures (gram-calories per minute per square centimeter). Potsdam*

Exposure	Radiation in gr.-cal. min. cm.²	Month	Hour
Under normal incidence	1. 278	May	Noon.
On horizontal plane	1. 113	June	Do.
On north wall	. 250	do	5 a. m.[1]
On east wall	. 911	do	7 a. m.
On south wall [2]	1. 019	October	Noon.
On west wall	. 911	June	5 p. m.
On north slope of 30°	. 654	do	Noon.
On east slope of 30°	1. 156	do	10 a. m.
On south slope of 30°	1. 276	May	Noon.
On west slope of 30°	1. 156	June	2 p. m.

[1] Also 7 p. m. [2] 1.016, February, noon.

TABLE 3.—*Solar radiation (gram-calories per square centimeter), with average cloudiness, received daily at the middle of the month. Potsdam*

Exposure	January	February	March	April	May	June	July	August	September	October	November	December
Under normal incidence	84	134	226	354	441	489	414	375	329	212	95	70
On horizontal plane	20	44	102	196	276	319	269	223	165	81	25	15
On north wall	0	0	0	1	11	23	14	4	0	0	0	0
On east wall	13	29	61	106	133	148	122	112	91	49	17	10
On south wall	74	106	146	158	136	120	113	143	184	157	82	65
On west wall	14	29	56	99	126	139	121	106	88	49	18	12
On north slope of 30°	0	0	15	91	176	228	183	124	50	0	0	0
On east slope of 30°	18	42	96	182	251	289	240	204	153	76	24	14
On south slope of 30°	54	91	161	248	303	326	283	263	235	149	63	45
On west slope of 30°	19	42	92	175	245	281	239	198	149	76	25	15

TABLE 4.—*Mean daily total of solar radiation (gram-calories per square centimeter), with clear sky and with average cloudiness, April–August. Potsdam*

Exposure	Radiation in gr.-cal. min. cm.²	
	Clear sky	Average cloudiness
Under normal incidence	869	415
South slope of 30°	563	285
Horizontal plane	512	257
East slope of 30°	469	233
West slope of 30°	469	228
North slope of 30°	329	160

THE ROOT PROBLEM OF MACRO-METEOROLOGY

By DR. FRANZ BAUR

[Berlin, Germany, April 10, 1928]

SYNOPSIS

The root problem of macro-meteorology is the answer to the question: Are the changes in the system of the general circulation of the atmosphere, to which after all the great weather abnormalities are traceable, occurrences which originate in the main in themselves, or is their origin for the most part to be looked for outside the earth? The purpose of the following investigations is to help to pave the way to the right answer to this fundamental question. It is therein shown that it can not be proved that there is any connection between changes in atmospheric circulation and cosmic occurrences, especially solar ones; it is shown, however, that there is a close connection between these changes on the whole and the foregoing temperature and pressure abnormalities on the earth itself. Changes in solar radiation have an influence worth mentioning on the general circulation of the atmosphere only when they find a resonance in the complex wave system of atmospheric circulation.

We know that great weather phenomena (macro-phenomena, by which I understand, not the weather of single days, but the general character of the weather extending over a longer period, say of weeks and months) stand in closest relationship with the great variations in the general circulation of the atmosphere and their single parts. The idea of the general circulation of the atmosphere comprises in this connection a whole complex of phenomena, viz, the exchange of air between the subtropical belts of high pressure and the equatorial zone, which takes place with relative regularity even if not at all always continuously, and the naturally discontinuous exchange of air between the subtropical and the polar regions which takes place in several contig ous "Zirkulationsstreifen" (1). For the understanding and forecasting of the great weather phenomena, the question of the *origin* of the great changes in the general circulation of the atmosphere and their single parts, is of fundamental importance. Two possibilities exist. *Either* it is a question of the *changes having for the most part their origin in themselves;* that is, according to which the condition B at any given point of time is determined by the foregoing condition A (terrestrial); *or*, the *origins* of these variations are *for the most part* to be looked for *beyond the earth.* The question as to which of these two possibilities is to be accepted as correct is the *fundamental question of macro-meteorology.*

If cosmic influences are chiefly responsible for the condition of the weather on the whole, then it is most probable that these influences consist of changes in solar radiation beyond the earth, since all changes in our atmosphere derive their energy from solar radiation. It is indeed often supposed that the great variations in the intensity of the general circulation of the atmosphere are determined by changes in extraterrestrial solar radiation. An exact examination of this supposition in the light of experience is not yet possible, since we have too little information about the actual changes in solar radiation. Certain points can however be deduced on the ground of some considerations which allow us to form a judgment on the question of whether the influences of possible changes in solar radiation are of *prime* or only subordinate importance.

The *first consideration* of this sort is the following: If changes in solar radiation, quantitative or qualitative, of any importance take place at all, these are very likely connected with *visible changes* in the sun's surface. We know to-day five such changes, namely, sun spots, faculæ, protuberances, the changing form of the corona, and the so-called solar contrast (i. e. the contrast between the brightness of the edge and center). The frequency of the faculæ changes almost exactly parallel with the sun spots. For the period 1887–1924, I found for the annual mean of numbers of sun spots and faculæ a correlation coefficient of *+0.89*. The changing form of the corona also stands in close covariation with the sun spot period. If solar activity is less, long rays are found parallel to the sun's equator, corresponding to the fact that then the spots occur in lower heliographic latitudes. If the number of spots is however great, so that they appear in higher latitudes, then the rays of the corona stretch out in all directions fairly evenly into space. Similarly, the frequency of the protuberances and the strength of the solar contrast appear to be connected with the frequency of sun spots. We can therefore obtain a general statistical survey of the different visible changes in the sun's surface, by selecting the sun spots, which have been longest under observation and which can be best expressed numerically. Accordingly, I examined by means of the correlation method, whether any connection exists between the number of sun spots and the intensity of the North Atlantic atmospheric circulation, which is a part of the general circulation which splits into single contiguous "Streifen" (stripes) in the temperate zone. As a measure of the intensity of the North Atlantic atmospheric circulation, I chose the pressure difference between Ponta Delgada and Iceland. (2)

In the first column of Table 1 occur the correlation coefficients between the monthly means of the difference of pressure Ponta Delgada-Iceland and the monthly means of Wolfer's numbers of sun spots occurring *simultaneously*, for every month of the year in the 50-year period 1874–1923. Any systematic relation is *not* apparent. With the exception of the coefficient for May they are all very small. In answer to the interpretation of this result as evidence that no connection worth mentioning exists between sun spots and intensity of atmospheric circulation, it can be put forward that there need not necessarily be the connection with the sun spots visible at the moment. v. Aufsess (3), for example, supposes that sun spots affect the weather only as long as they are in the process of formation, and not yet visible to the eye. I have therefore also calculated the correlation coefficients between the monthly means of the pressure difference Ponta Delgada-Iceland and the increase in the number of sun spots *from* the *past* and *up to* the *next* month. The resulting coefficients occur in the second and third columns of Table 1. Here also only small coefficients were found, and *no* systematic connection. Out of 36 coefficients in Table 1, there are 3 which exceed twice the standard error, that is, only a single one more than could be expected with a distribution of the coefficients according to Gauss' Law. It is to be noticed that the large coefficient of the second column is not independent of that in the first column.

Since, strictly speaking, lower correlation coefficients do not yet mean that no connection whatsoever exists between two phenomena, but only that this is no rectilinear relation, I have also calculated the correlation ratios which are a measure of the closeness of the connection for every kind of law of dependence. Here also the result was that *no connection* could be proved between sun spots and intensity of North Atlantic air circulation.

The *second consideration* with the help of which we are able to form a judgment as to whether the great variations in the general circulation of the atmosphere are caused chiefly by changes in solar radiation, is that a change in the solar constant, or a change in the diathermancy of the atmosphere caused by an extraterrestrial influence, will change the intensity of the air circulation, not in all parts in the same degree, but at least *in the same sense.* If, for example, through an increase of temperature in lower latitudes which has its origin, not in limited local conditions, but in changes in extraterrestrial solar radiation, an increase in the atmospheric circulation in the North Atlantic "Zirkulationsstreifen" is caused, there is no reason why such an increase should not also be apparent in the North Pacific "Zirkulationsstreifen," even if the amount of increase may be different here and there. There would have to be, therefore, if the changes in solar radiation are of determining importance, positive correlations of the intensity of circulation between the individual "Zirkulationsstreifen" and—at least in the winter half year in the southern hemisphere—positive correlations of pressure between the nuclei of the subtropical belt of high pressure.

A comparison of the west component of the windways in Potsdam (Germany) and in Boston (Mass.) produced (4) a distinct positive correlation, because both belong in general to one and the same "Zirkulationsstreifen." Especially clear is the correlation of the southwest component in Potsdam and the northwest component in Boston, to be explained by the fact that Potsdam lies on the east side and Boston on the west side of the North Atlantic "Zirkulationsstreifen". On the other hand, no correlation exists between the windways over Potsdam and those of Portland (Oreg.) in the west of North America, and none between the windways of Boston and Portland, just because Portland belongs to a different "Zirkulationsstreifen," that of the North Pacific.

The comparison of *contemporary changes of pressure* in several places lying in the *subtropical region of high pressure* has been made for the southern hemisphere, since the subtropical region of high pressure in the northern hemisphere, on account of its great land masses (chiefly Asia) extending into high latitudes, is less regular and less clearly defined. In order to obtain a reliable result, observations extending over 50 years were made use of for this purpose. For this reason Cape Town and St. Helena on the border of the South Atlantic anticyclone had to remain out of consideration, since of both places no such long *homogeneous* series are available. The chosen places Buenos-Aires and Cordoba, Mauritius and Sydney (Austral.) lie, in the winter half year, in the middle of the southern high pressure region. There would have to be therefore, at least in winter, positive correlations of the contemporary monthly means of air pressure for these places, if the whole region of high pressure experiences uniform changes of intensity. Instead of this, however, as Table 2 shows, the correlation between the atmospheric pressure at Sydney (Austral.) and that in the Argentine (Buenos Aires + Cordoba) is negative almost throughout the whole year, especially, however, just in winter; also the correlation of the Argentine with Mauritius is for the most part negative. The correlation of the air pressure over Mauritius with that over Sydney is, maybe, more often positive than negative, but the largest positive coefficients are found, not for the winter proper (June-August), but for the transition months March and September. Among the 36 coefficients of Table 2 occur five which exceed twice the standard error m, whilst in Table 1 only three such coefficients appeared, and with accidental distribution (distribution according to Gauss' Law) the probability of a correlation coefficient 2 m is 1:22. It is therefore quite possible that in the five largest correlation coefficients physical relations which really exist between the pressure of the three chosen parts of the southern high pressure belts are expressed; but these relations are not of the kind enabling one to speak of uniform variations of intensity of the whole high pressure region.

These examinations showed that *no connections* exist admitting of the conclusion that the great changes of intensity in the exchange of air in the "Zirkulationsstreifon" are determined for the most part by changes in solar radiation reaching the earth. What can now be said about the connection between changes in circulation abnormalities *and foregoing conditions in the atmosphere itself?*

In order to make this clear, we can first put the *preliminary question, "Does the distribution of air masses in the northern hemisphere exercise a systematic influence on the intensity of the North Atlantic atmospheric circulation, either to preserve or change it?*

In answer to this question, the average departure of pressure was calculated for 44 stations in the northern hemisphere for the period 1887/1916.

(*a*) In those months in which the North Atlantic atmospheric circulation was especially intensive, and also remained the same in the next month.

(*b*) In months with very intensive circulation, followed by a considerably too weak circulation.

(*c*) In months with very weak circulation which remained unchanged in the next month.

(*d*) In months in which the North Atlantic atmospheric circulation was very weak, whilst it was in the following months considerably too intensive.

It was regarded as a considerable deviation from the normal circulation when, in the first month for which the distribution of pressure was calculated, the departure from the normal pressure gradient between Ponta Delgada and Iceland in the months October–April amounted at least to 4 mm., and in the months May–September, 3 mm., whilst in each case for the succeeding month 2 or 1.5 mm. were taken as the minimum.

The results obtained for February are shown in Figures 1–4. Figure 1 shows how, in those months of February, in which an especially intensive North Atlantic atmos-

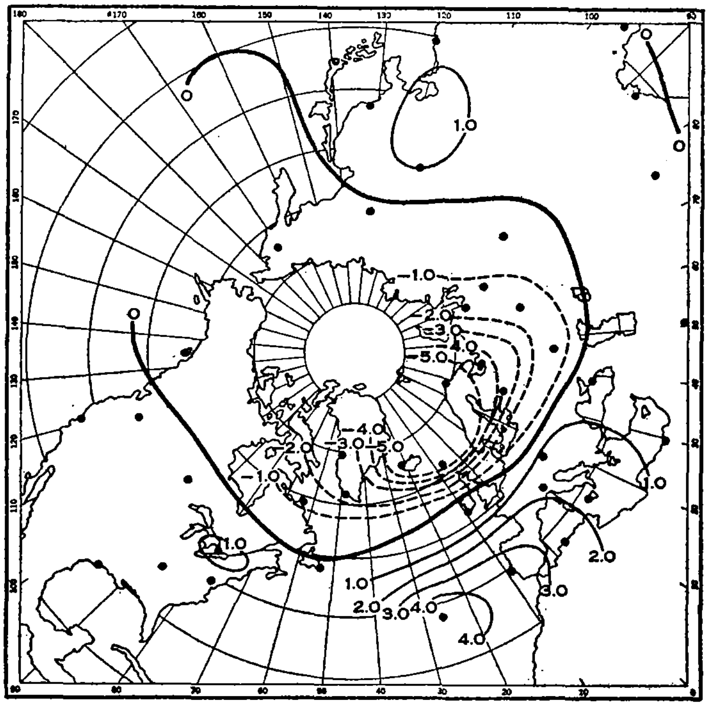

FIG. 1.—Mean pressure departures (mm.) in February, 1894, 1897, 1903, 1907, 1908, 1910, and 1914, with very *strong* North Atlantic air circulation, which *continued* during the succeeding March

pheric circulation was followed by an equally intensive one in March, a limited region of deficient pressure occurs round the pole; whilst in middle and lower latitudes a belt of excess pressure lies. The reverse abnormality is seen in Figure 2—around the pole a region of excess pressure and in lower latitudes deficient pressure. This distribution of pressure exists with very weak North Atlantic air circulation, which continues during March. Figure 3 presents a totally different picture. It represents the abnormality of those months of February with very strong North Atlantic circulation, which *changes* in March to one of little intensity. Here we have an arrangement of regions of abnormalities, not in zones but in meridional stripes. To the great contrasts in pressure in one and the same latitude, correspond, as is shown by the carrying out of the same investigations for temperature abnormalities (5), similar contrasts in temperature. In a similar manner, positive and negative abnormalities of pressure alternate in Figure 4 in one and the same latitude; but here, in contrast to Figure 3, near Iceland, excess pressure exists, corresponding to the circumstance that Figure 4 represents the mean departures of pressure with very weak North Atlantic circulation in February changing to strong in March. Similar results were found for the other months of the year (5).

The *fundamental difference* between the distribution of pressure in the case of the continuation of the existing abnormality of circulation and that before the coming of

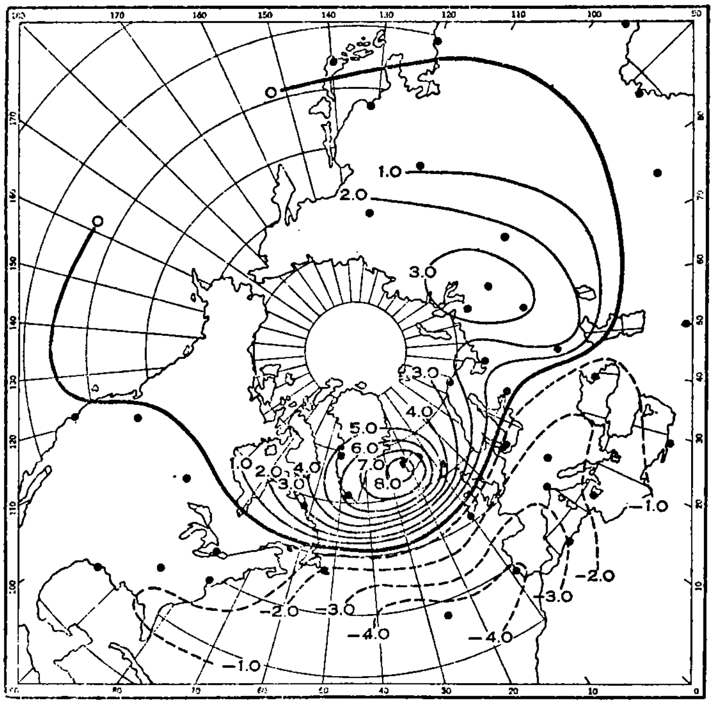

FIG. 2.—Mean pressure departures (mm.) in February, 1888, 1892, 1899, 1900, and 1901, with very *weak* North Atlantic air circulation, which *continued* during the succeeding March

a change from deficient to excessive circulation intensity or vice versa is that in the first case the meridional gradients are above or below normal, in the latter case

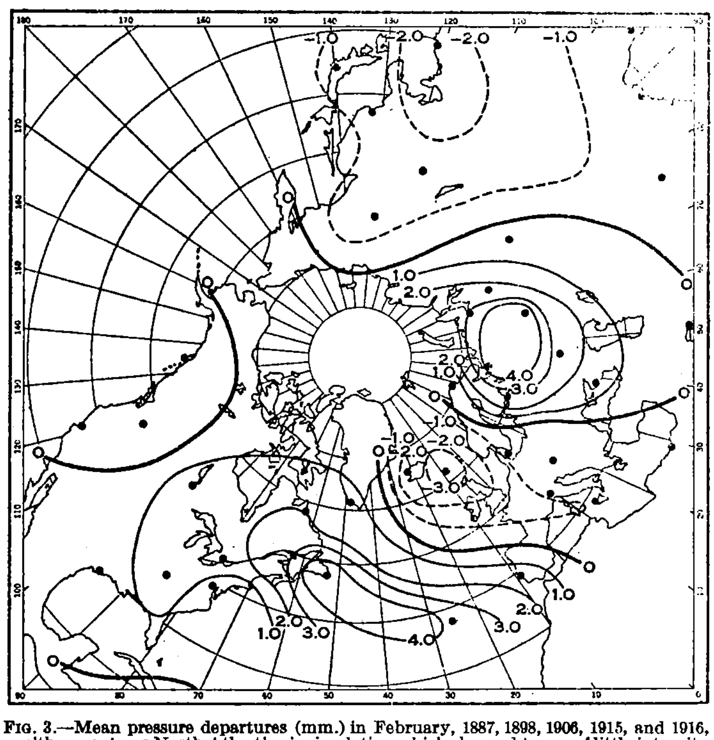

FIG. 3.—Mean pressure departures (mm.) in February, 1887, 1898, 1906, 1915, and 1916, with very *strong* North Atlantic air circulation which changed to one of little intensity in the succeeding March

the zonal. Through the abnormal zonal gradients of pressure abnormal meridional displacements of air are naturally caused, which bring about the change in cir-

culation abnormality. We can, therefore, on the ground of these results answer the above preliminary question as follows: *Whether an existing abnormality in the North*

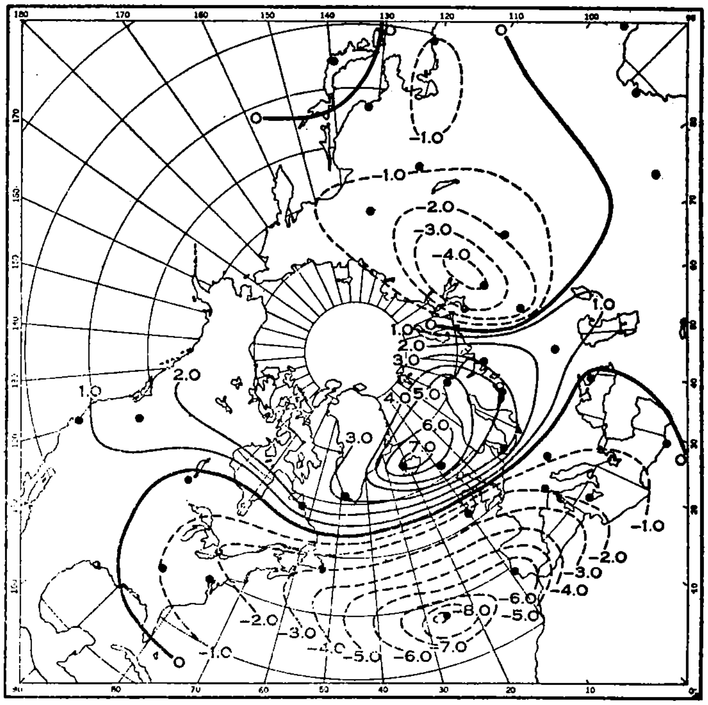

FIG. 4.—Mean pressure departures (mm.) in February, 1890, 1895, 1902, and 1912, with very *weak* North Atlantic air circulation, which *changed* in the succeeding March to a strong one

Atlantic air circulation (apart from temporary changes caused by passing waves of pressure) *continues for a still longer time, or is reversed, depends essentially on whether*

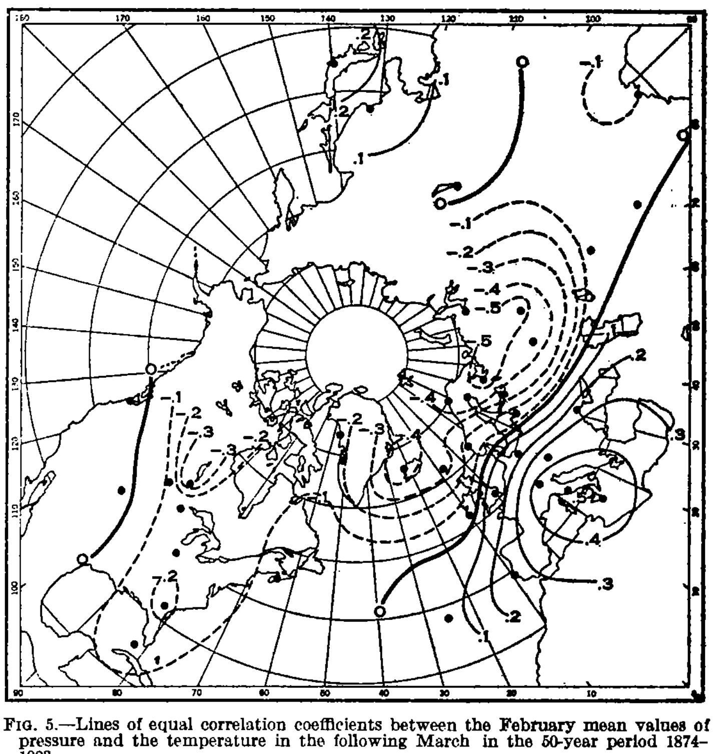

FIG. 5.—Lines of equal correlation coefficients between the February mean values of pressure and the temperature in the following March in the 50-year period 1874–1923

the whole polar region shows a uniform abnormality of pressure, or whether zonal contrasts exist in the pressure deviation of higher latitudes. We have here then an evident dependence of changes in atmospheric circulation on preceding *terrestrial* conditions.

We can also verify the great dependence of the intensity of the North Atlantic air circulation on *preceding* atmospheric conditions by means of such phenomena of weather as stand in specially close relationship with simultaneous abnormalities of circulation. The mean temperature for March in Germany stands in rigid rectilinear stochastic relationship with the simultaneous mean for March of the difference of pressure Ponta Delgada-Iceland, taken as standard for the North Atlantic atmospheric circulation. The correlation coefficient for the 50-year period 1874–1923 is +0.71. It is now the question whether physically explainable connections (*not* accidental) can be determined betweeen the March temperature of Germany and the distribution of pressure for the February immediately preceding. For this purpose the correlation coefficients of the pressure for February for the period 1874–1923 were calculated for 38 stations in the Northern hemisphere with the temperature of Germany in the following March. The result is set forth graphically in Figure 5. This figure gives a quite clear picture; positive correlation with the pressure in Middle and South Europe, negative corrrelation with the pressure in higher latitudes from North America to the Yenesei. The correlation coefficients are for certain places very considerable, e. g., Rome +0.48, Malta +0.48, Sswerdlowsk (the former Katherinburg on the east slope of the Ural Mountains) −0.52, Kem (on the White Sea) −0.57. That this is not accidental we see from the fact that we get for the two separate 25-year periods 1874–1898 and 1899–1923, at least for the European-Asiatic part, almost the same correlations. With regard to a detailed mathematical criticism of the stability of the correlation, reference must be made to the original work (**6**).

It is especially to be noticed that the nuclei of high correlation are without exception to be found in prominent places (places having especial meteorological importance), the highest positive correlation where at this time of year there is a root region of stratospheric pushes toward the north whilst the nuclei of negative correlation occur where the chief exits of polar air masses are—east of the Rocky Mountains, east of Greenland, and near Nova Zembla.

If we now attempt to valuate these facts with regard to the chief problem set forth at the beginning of this article, the question arises as to whether the connection between atmospheric pressure for February and the temperature for March in Germany varies according to whether we are in a sun spot maximum or minimum. It is of course conceivable that changes in solar radiation which occur simultaneously with the sun spots help or hinder the relations found. I have therefore, at least for Europe, calculated the correlation coefficients between February pressure and March temperature, for Germany separately also, for the 25 years in which the numbers of sun spots in March were above normal, and for those 25 years in which they were below normal. In doing this the mean values for the thus selected 25 per cent years were naturally used as a starting point. As a secondary result it was found that, in accordance with former investigations (1), that the differences in the mean values for months of maximum and minimum sun spots respectively, are only *very slight*. The mean temperature for March is for example (in Germany) in the months of maximum sun spots only about 0.30° C. less than in the months of minimum spots.

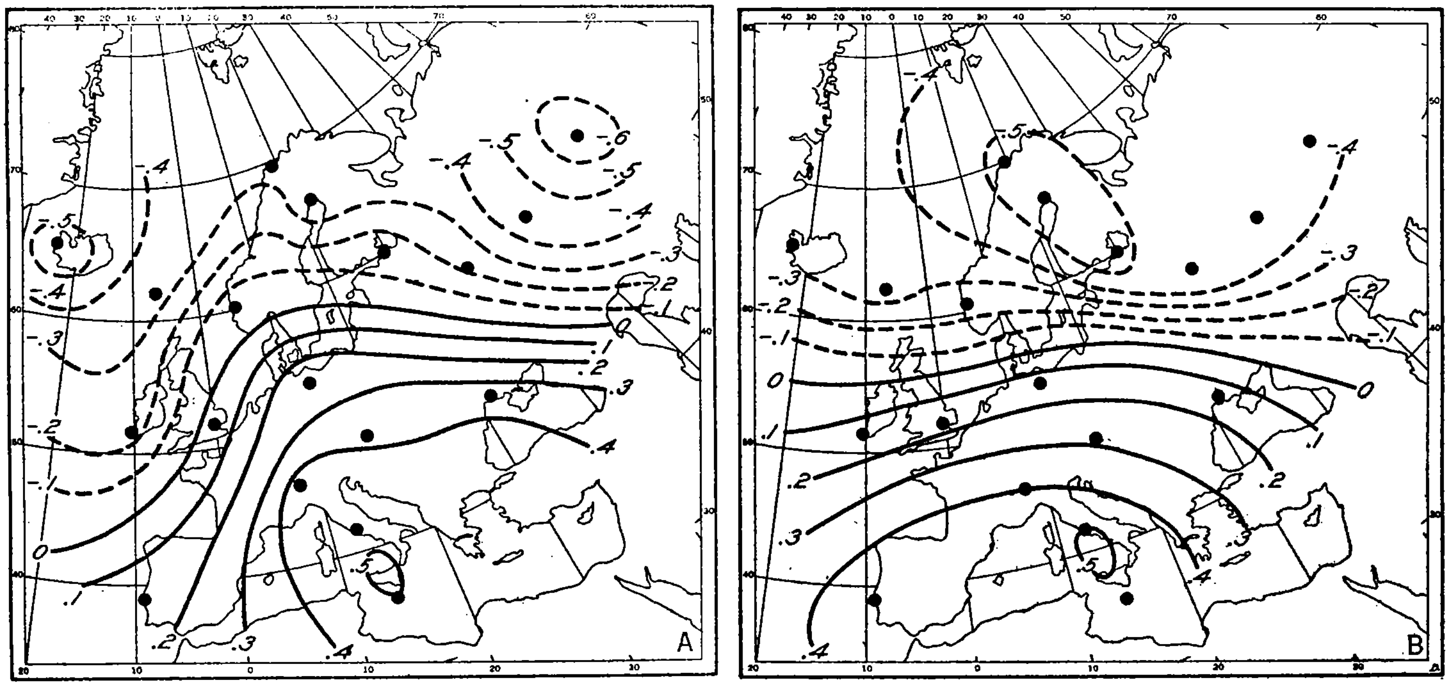

FIG. 6.—Lines of equal correlation coefficients between the February pressure and the temperature in Germany in the following March; A, in months *below* normal sun-spot activity, and B, in months *above* normal sun-spot activity

The correlation results in the months with below normal and above normal sun-spot activity are set forth graphically in Figures 6 and 7. A difference between the two sets of results exists only in so far as the largest negative correlation lies in the one case, when sun spots are numerically above normal, in North Scandinavia and Finland; in the other case, when the number is below normal, it is divided into two parts, one near Iceland and one on the Ural Mountains. Whether an actual relation with the sun spots is here evident can not with certainty be decided to-day. The fact however, that the two sets of results, apart from the slight difference mentioned, are in their chief features so extraordinarily similar, is a new proof of the surpassing and decisive importance of the foregoing weather conditions "Witterungsvorgeschichte."

If we survey once again all these investigation results, then we must answer the question set forth at the beginning of this article as follows. That evidently, for variations in atmospheric circulation and for the whole formation of the weather, *the preceding condition of terrestrial weather is of more decisive importance than cosmic influences*. With this realization, a firm foundation has been secured to enable us to approach the *exploration of the problem of long-range forecasting*. In consideration of the problem of periodicity in the course of the weather, this realization means that possible periodic variations in solar radiation have a greater influence on terrestrial weather conditions only when they find a resonance in the complex system of the general circulation of the air, capable as it is of manifold oscillations in itself (8).

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TABLE 1.—*Correlation coefficients (multiplied with 100) between the monthly means of pressure difference, Ponta Delgada, Iceland, and the sun-spot numbers*

(Period 1874/1923)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
a. With the *simultaneous* monthly means of sunspot numbers	−16	+14	+1	±0	**−40**	+1	−3	−3	+18	+9	+14	−6
b. With the *increase* of the sunspot numbers from the *past* month	+5	−9	−20	+5	**−29**	−6	+8	−3	−14	+6	+10	+3
c. With the *increase* of the sunspot numbers up to the *next* month	+3	−8	−4	−8	+9	−16	**−36**	+11	−16	+17	−9	+0

The big coefficients are greater than twice the standard error.

TABLE 2.—*Correlation coefficients (multiplied with 100) of the simultaneous monthly means of pressure at stations of the subtropical belt of high pressure of the Southern Hemisphere*

(Period 1875/1924)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
a. Argentina (2 stations) and Mauritius	+7	+21	−14	−1	−1	+14	**−33**	−25	+12	−14	+11	+14
b. Mauritius and Sydney (Australia)	+21	+5	**+28**	+18	+1	−2	+14	+10	**+33**	−5	+7	−2
c. Sydney (Australia) and Argentina (2 stations)	+8	+21	−19	**−32**	−20	−17	**−32**	−10	−17	−16	−9	+19

The big coefficients are greater than twice the standard error.

HIGH INTENSITY OF SOLAR RADIATION IN THE SPRING OF 1928

By P. GOTZ

[Die Naturwissenschaften, Heft 23, June 8, 1928, p. 474]

From experience it is known that in every year spring brings the highest value of total heat intensity of the sun. It is true that at that time the sun's rays have a path through the air strata longer than that traversed in summer, that on an average the ozone stratum is thicker,[1] and that in the first half of the year the atmosphere contains more floating particles (*Luftplankta*),[1] but at the same time it is in very large degree winter-dry. Measurements to date at Arosa (1,860 meters) show the maximum radiation in the year 1923, when the value reached was 1.6 calories per minute per square centimeter.

The spring of the present year brings especially high values. By reason of a rather large number of measurements not only with the Michelson actinometer, but also directly with the Abbot silver disk, the values under J' in the following table are trustworthy to within one-half of one per cent. In addition the table contains the time of observation, the corresponding elevation of the sun (h), the vapor pressure (e) and the relative humidity ($r. F.$).

Under J are entered the values of solar radiation theoretically possible when the atmosphere is entirely free from water vapor and dust and only the air molecules can cause depletion, that is, for a turbidity factor having

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